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FUEL CONTROL FAILURE DETECTION BASED ON POST O_2 SENSOR

FIELD OF THE INVENTION

[0001] The present invention relates to diagnostic systems for vehicles, and more particularly to a diagnostic system that detects engine air to fuel (A/F) ratio imbalance and exhaust leaks.

BACKGROUND OF THE INVENTION

[0002] During the combustion process, gasoline is oxidized and hydrogen (H) and carbon (C) combine with air. Various chemical compounds are formed including carbon dioxide (CO_2), water (H_2O), carbon monoxide (CO), nitrogen oxides (NO_x), unburned hydrocarbons (HC), sulfur oxides (SO_x), and other compounds.

[0003] Automobile exhaust systems include a catalytic converter that reduces emissions by chemically converting exhaust gas into carbon dioxide (CO_2), nitrogen (N), and water (H_2O). Exhaust gas oxygen (O_2) sensors generate signals indicating the oxygen content of the exhaust gas. One O_2 sensor monitors the oxygen level associated with the inlet of the catalytic converter.

[0004] The inlet O_2 sensor provides a primary feedback signal to the fuel system. The signal that is generated by inlet O_2 sensor is used to control the A/F ratio of the engine. Maintaining the A/F ratio at the chemically correct or stoichiometric A/F ratio improves the efficiency of the catalytic converter. A second or outlet O_2 sensor monitors oxygen levels of the exhaust gas that exits the catalytic converter. The outlet O_2 sensor provides a secondary feedback signal to the fuel system. An optimal control range of the outlet O_2 sensor signal is defined by emission performance. The fuel system shifts an

offset or bias of the inlet O_2 sensor signal when the outlet O_2 sensor signal is outside of a predetermined control range.

[0005] A/F ratio imbalance within individual cylinders of an engine and exhaust leaks can lead to undesired exhaust emission performance. As a result, it is necessary for a diagnostic system to identify A/F imbalance or leak conditions.

SUMMARY OF THE INVENTION

[0006] Accordingly, the present invention provides an engine diagnostic system including a catalytic converter and an outlet O_2 sensor. The outlet O_2 sensor generates an outlet signal that is based on an oxygen level of exhaust gases exiting the catalytic converter. A controller adjusts a secondary fuel trim based on the outlet signal. The controller indicates a fault status if the secondary fuel trim has achieved a fuel trim limit and the outlet signal is out of a diagnostic range.

[0007] In one feature, the engine diagnostic system further includes an inlet sensor that generates an inlet signal based on an oxygen level of exhaust gases entering the catalytic converter. The inlet signal is biased based on the outlet signal.

[0008] In one feature, the secondary fuel trim has achieved the fuel trim limit when an inlet sensor bias has achieved a bias limit and the outlet signal is outside of a control range.

[0009] In another feature, the controller indicates a pass status if a secondary fuel trim is less than the fuel trim limit.

[0010] In still another feature, the controller indicates a pass status if the outlet signal is within said diagnostic range.

[0011] In another feature, a fault for a given sample is indicated if the secondary fuel trim has achieved the fuel trim limit and the outlet signal is out of the diagnostic range.

[0012] In yet another feature, the fault decision is confirmed if the secondary fuel trim has achieved the fuel trim limit and the outlet signal is out of the diagnostic range for a threshold period during a monitoring period.

[0013] In still another feature, the fault status is indicative of a cylinder air to fuel (A/F) ratio imbalance or an exhaust leak.

[0014] Further areas of applicability of the present invention will become apparent from the detailed description provided hereinafter. It should be understood that the detailed description and specific examples, while indicating the preferred embodiment of the invention, are intended for purposes of illustration only and are not intended to limit the scope of the invention.

BRIEF DESCRIPTION OF THE DRAWINGS

[0015] The present invention will become more fully understood from the detailed description and the accompanying drawings, wherein:

[0016] Figure 1 is a functional block diagram of a vehicle including a controller that performs a secondary fuel trim diagnostic according to the present invention;

[0017] Figure 2 is a flowchart detailing steps of the secondary fuel trim diagnostic according to the present invention; and

[0018] Figure 3 is a signal flow diagram illustrating exemplary logic of the secondary fuel trim diagnostic.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

[0019] The following description of the preferred embodiments is merely exemplary in nature and is in no way intended to limit the invention, its application, or uses. For purposes of clarity, the same reference numbers will be used in the drawings to identify similar elements.

[0020] Referring now to Figure 1, an engine system 10 includes an engine 12, an exhaust system 14 and a controller 16. Air is drawn into the engine through an intake manifold 18. The air is combusted with fuel inside cylinders of the engine 12. Exhaust gas produced by combustion exits the engine through the exhaust system 14. The exhaust system 14 includes a catalytic converter 22, a pre-catalyst or inlet O_2 sensor 24, and a post-catalyst or outlet O_2 sensor 26. The exhaust gas is treated in the catalytic converter 22 and then released to the atmosphere.

[0021] The inlet and outlet O_2 sensors 24 and 26 generate signals that are communicated to the controller 16. The inlet and outlet O_2 sensors 24, 26 provide inlet and outlet A/F ratio signals. The controller 16 communicates with a fuel system 28, which regulates fuel flow to the engine 12. In this manner, the controller 16 adjusts and controls the A/F ratio of the engine 12.

[0022] The inlet and outlet O_2 sensors 24,26 are typically narrow range switching sensors. It is appreciated, however, that the inlet and outlet O_2 sensors 24,26 are not limited to narrow range type switching sensors. Voltage output signals that are generated by the sensors 24,26 are based on the O_2 content of the exhaust gases passing the O_2 sensors relative to stoichiometry. The signals transition between lean and rich in a narrow A/F ratio range that brackets the stoichiometric A/F ratio. The O_2 sensor signal that is generated by an operable sensor oscillates back and forth between rich and lean values at a relatively constant frequency.

[0023] The controller 16 regulates the fuel flow based on the O_2 sensor signals. During primary fuel control, the controller 16 regulates fuel flow to the engine 12 based on the signal of the inlet O_2 sensor 26. For example, if the inlet O_2 sensor signal indicates a lean condition, the controller 16 increases fuel flow to the engine 12.

Conversely, if the inlet O_2 sensor signal indicates a rich condition, the controller 16 decreases fuel flow to the engine 12.

[0024] The outlet O_2 sensor provides feedback that is used to adjust the inlet O_2 sensor. More particularly, the inlet O_2 sensor signal is adjusted by a bias or offset that is based on the outlet O_2 sensor signal. For example, if the outlet O_2 sensor 26 detects that the signal is outside of a control range, the controller 16 correspondingly adjusts the inlet O_2 sensor signal bias. It is desired to maintain the outlet O_2 sensor signal within a control range that corresponds to optimum emissions system performance. An exemplary control range is 600 mV to 700 mV. Thus, the influence of the outlet O_2 sensor 26 on the inlet O_2 sensor signal 24 is limited by a maximum offset or bias. In other words, the inlet O_2 sensor signal bias must be between upper and lower bias limits.

[0025] A diagnostic range for the outlet O_2 sensor signal is also provided. The diagnostic range is defined by upper and lower thresholds that exceed the respective thresholds of the control range. If the outlet O_2 sensor signal is outside of the diagnostic range, the diagnostic indicates an engine fault for that data sample. The engine fault could include an A/F ratio imbalance within a cylinder, an exhaust leak and/or other engine problems. The diagnostic range is determined using empirical data for engine configurations. For example, faulty engine conditions for the engine configuration are simulated. The outlet O_2 sensor signal is reviewed to determine the signal threshold between acceptable engine operation and faulty engine operation. The above-mentioned control range is within the diagnostic range.

[0026] Referring now to Figure 2, the secondary fuel trim diagnostic will be described in detail. In step 100, control determines whether enablement requirements are met. If so, control continues in step 102. Otherwise control loops back. The enablement

requirements include closed-loop fuel control, secondary fuel control and/or no intrusive diagnostics running. If the engine is operating in open-loop fuel control and/or secondary fuel control is disabled as a result of a vehicle event such as wide-open throttle acceleration, the secondary fuel control diagnostic is also not enabled. The secondary fuel control diagnostic is not enabled when system diagnostics that intrusively impact exhaust A/F ratio are running.

[0027] In step 102, control determines whether the secondary feedback control is at its maximum offset. This occurs when the outlet oxygen sensor signal is outside of the control range and the inlet oxygen sensor bias has achieved a bias limit. If the secondary feedback control is not at its maximum offset, a pass status is indicated in step 104 and control ends. Otherwise, control determines whether the outlet oxygen sensor signal is outside of the diagnostic range in step 106. If false, control continues in step 104. If true, control indicates a fail status in step 108 and ends.

[0028] Referring now to Figure 3, a signal flow diagram illustrates exemplary logic of the secondary fuel trim diagnostic of the present invention. The inlet and outlet O_2 signals are sent to the controller 16. A feedback outlet O_2 sensor signal is sent to a bias circuit 300. The bias circuit 300 determines the offset or bias signal sent to the inlet sensor. The bias signal is limited to a maximum offset or bias limits. The bias signal is also sent to a first comparator circuit 302 that compares the bias signal to the bias limits. The output of the first comparator circuit 302 is sent to a first decision gate 304 and is 0 if the bias signal is inside the bias limit and is 1 if the bias signal is equal to a bias limit.

[0029] The outlet O_2 signal is sent to a second comparator 306. The second comparator compares the outlet O_2 signal to a control range. The output of the second comparator 306 is 1 if the outlet O_2 signal is outside of the control range. Otherwise, the output of

the second comparator 306 is 0. The output of the second comparator is sent to the first decision gate 304. The output of the first decision gate 304 is 1 if the outputs of the first and second comparators are 1. That is to say, the output of the first decision gate 304 is 1 if the outlet O_2 signal is outside of the control range and the bias signal is equal to a bias limit. Otherwise, the output of the first decision gate 304 is 0. The output of the first decision gate 304 is sent to a second decision gate 308.

[0030] The outlet O_2 signal is also sent to a third comparator 310. The third comparator compares the outlet O_2 signal to the diagnostic thresholds. The output of the third comparator 310 is 1 if the outlet O_2 signal is outside of the diagnostic threshold range. Otherwise, the output of the third comparator 310 is 0. The output of the third comparator is sent to the second decision gate 308. The output of the second decision gate 308 is 1 if the outputs of the first decision gate 304 and the third comparator 310 are 1. That is to say, the output of the second decision gate 308 is 1 if the outlet O_2 signal is outside of the control range, the bias signal is equal to a bias limit and the outlet O_2 signal is outside of the diagnostic threshold range. Otherwise, the output of the second decision gate 308 is 0. An output of 0 indicates a pass and an output of 1 indicates a fail or fault.

[0031] The controller 16 can indicate a fault to the vehicle operator or flag the fault in memory immediately upon the occurrence of a fault and/or after a predetermined time status. The controller 16 can also perform the secondary fuel control diagnostic M times and flag a fault if the fail status occurs N out of M times, where $N \leq M$. Another alternative embodiment flags a fault if the fail status occurs a threshold number of times during a predetermined period.

Those skilled in the art can now appreciate from the foregoing description that the broad teachings of the present invention can be implemented in a variety of forms. Therefore, while this invention has

been described in connection with particular examples thereof, the true scope of the invention should not be so limited since other modifications will become apparent to the skilled practitioner upon a study of the drawings, the specification and the following claims.